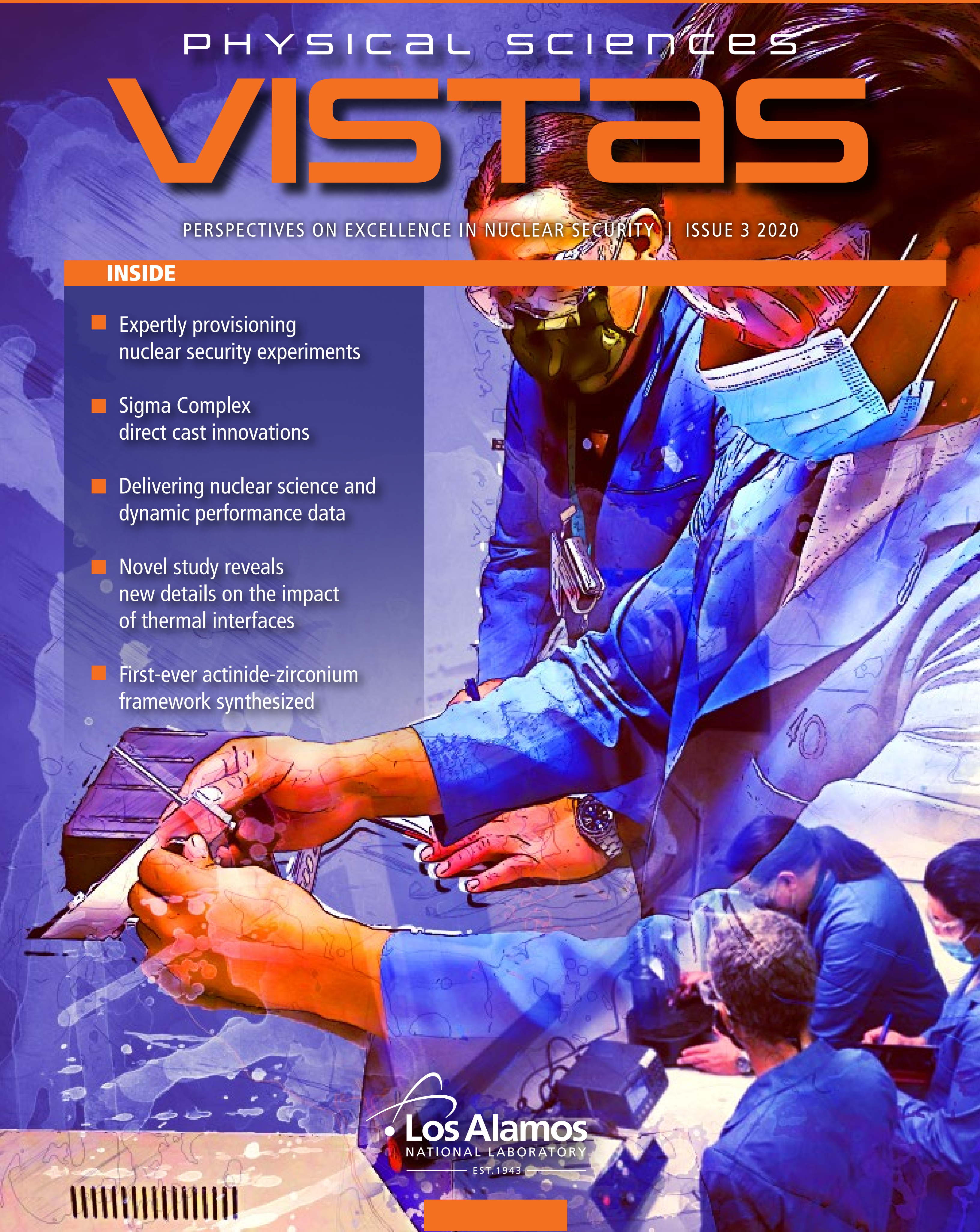
PHYSICAL SCIENCES

VISTAS

PERSPECTIVES ON EXCELLENCE IN NUCLEAR SECURITY | ISSUE 3 2020



INSIDE

- Expertly provisioning nuclear security experiments
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Jason Burkhart gives a thumbs up to ROCO's confined space rescue team member Michael Romero before he enters LANSCE drift tube linear accelerator tank-3 to perform a one-of-a-kind welding repair. Burkhart was part of a team that successfully executed the high-hazard operation to repair a crack that had rendered the half-mile-long accelerating structure inoperable.

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On the cover: Tomas Martinez and Carlos Archuleta mount a mock-up Z machine sample for sectioning. Inset: Jeremy Mitchell observes as measurements are performed on the sample.

Photos in this issue were taken in accordance with COVID protocols at the time.

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FROM TONI'S DESK

Toni Taylor, Associate Laboratory Director for Physical Sciences

We are now entering our ninth month of standing vigilant in preventing the spread of COVID-19 in our Laboratory community. I want to thank all of you for your diligence. It is through your efforts that during this time we have been able to successfully execute on many mission deliverables.

With respect to mission execution, I would like to take the opportunity to make a couple of introductions that are particularly relevant to our organization's work in nuclear security, the focus of this issue of *Physical Sciences Vistas*.

First, Michael Furlanetto has joined the directorate as our Los Alamos Neutron Science Center (LANSCE) user facility director (LUFD). LANSCE is our premier accelerator-based user facility for research underpinning Laboratory missions in national security, energy security, and fundamental science, and draws more than 700 user visits annually. Previously Mike was the deputy program director for the Office of Experimental Sciences. He brings to the LUFD role his experience in overseeing stockpile-related experimental research in nuclear physics, material science, high-energy-density physics, and implosion hydrodynamics. As LUFD, Mike leads the overall activities on the LANSCE mesa. He is developing a strategy, working in partnership with LANL leadership, for the modernization of the LANSCE accelerator and associated facilities, which will be implemented through an Accelerator Strategy Office (described below).

Second, I would like to announce the creation of the Accelerator Strategy Office (ASO). Los Alamos has a long-standing leadership role in the development and deployment of particle accelerators for national security needs—and given the importance of this area to the Laboratory, the 2021 Lab Agenda defines Objective 2.2 as the advancement of accelerator science, engineering, and technology to enable future stewardship capabilities. Reporting to the LUFD, the ASO will maximize our support for current and planned major accelerator-related scientific projects, including Pu@pRad, the LANSCE Front-End Upgrade, and Dynamic Mesoscale Materials Science Capability (DMMSC) initiatives. It will also ensure that both strategic planning and partnerships are well positioned to serve LANL's internal and external stakeholders and our capture efforts for accelerator-centric projects. The ASO is led by John P. Tapia, whose diverse background and record of accomplishment in program and project execution positions him perfectly as office director.

In this issue, highlights of our outstanding R&D supporting the Laboratory's nuclear security mission include the following.

- The essential nuclear materials science contributions of MST's Materials Properties Team to a range of Lab missions, operations, and initiatives.
- Work in the Sigma Complex supporting NNSA's Advanced Manufacturing Development milestones by members of Sigma Division and colleagues across the Laboratory and other NNSA sites.
- Greg Dale's role in the Lab's molybdenum program and today as a technical lead on the Scorpius project.
- Measurements that reveal the role thermal interfaces play in dynamic compression experiments.
- The first-ever synthesis of an actinide framework, which offers opportunities for understanding these structures as potential radioactive waste forms and provides new models of actinide species transport in the environment.

This issue also showcases, as part of our commitment to simultaneous excellence in mission operations and community relations,

- the successful high-hazard repair of the LANSCE accelerator, which resulted in a large team Laboratory Distinguished Performance Award, and
- a virtual Summer Physics Camp for Young Women that brought together participants from around the world, even as COVID kept them socially distant in their homes.

As a preview, the next *Vistas* issue is dedicated to excellence in community relations.

Toni

From left: Jeremy Mitchell observes as Tomas Martinez and Carlos Archuleta perform measurements on a cold lab mock-up of a Z machine sample.

Expertly provisioning **nuclear security experiments** — *Materials Properties Team's behind-the-scenes contributions are essential*

Long before a nuclear materials discovery is made or a national security milestone completed, members of the Materials Properties Team in Nuclear Materials Science (MST-16) have been deftly preparing the experiment. The plutonium studies that take place at Los Alamos and across the DOE Complex could not be performed without the team's agile response to the one-of-a-kind conditions of plutonium sample preparation.

"We take great pride in our ability to quickly adapt our resources to new projects and challenging experiments or finding solutions to complex problems that are unique to nuclear materials research," said team member Jeremy Mitchell.

GET THE DETAILS

Materials Properties Team members: Najeb Abdul-Jabbar, Carlos Archuleta, Chris Cordova, Matt Curtis, Meghan Gibbs, Jessica Hebert, Tomas Martinez, Jeremy Mitchell, Scott Parker, Adam Phelan, Mike Ramos, Gio Romero, Paul Tobash, Mark Wartenbe (Nuclear Materials Science, MST-16). **Technical contact:** Mike Ramos

The team includes skilled tradesmen, machinists, scientists, and engineers with backgrounds in metallurgy, nuclear engineering, chemistry, physics, and geology. The team's expertise includes materials synthesis, specialized sample preparation, and materials properties measurements.

Their work supports the Lab's 30 pits per year mission and surveillance and sustainment efforts, informs Office of Environment, Safety, and Health initiatives and radiological equipment installations, and contributes materials vital to the success of Laboratory Directed Research and Development projects.

"Most of our work is on plutonium, which requires exceptional care and expertise when handling," Mitchell said. The team's most common experiment involves prepping small samples of plutonium—between 0.1 and 10 grams—that are used for a number of experiments at LANL, most often in the Lab's Plutonium Facility.

Beyond Los Alamos, the team is responsible for work on mission-critical programs at sister laboratories. For example, the team ships samples to Sandia National Laboratories' Z Pulsed Power Facility to be used in experiments that range from applied weapons to fundamental energy research.

continued on next page

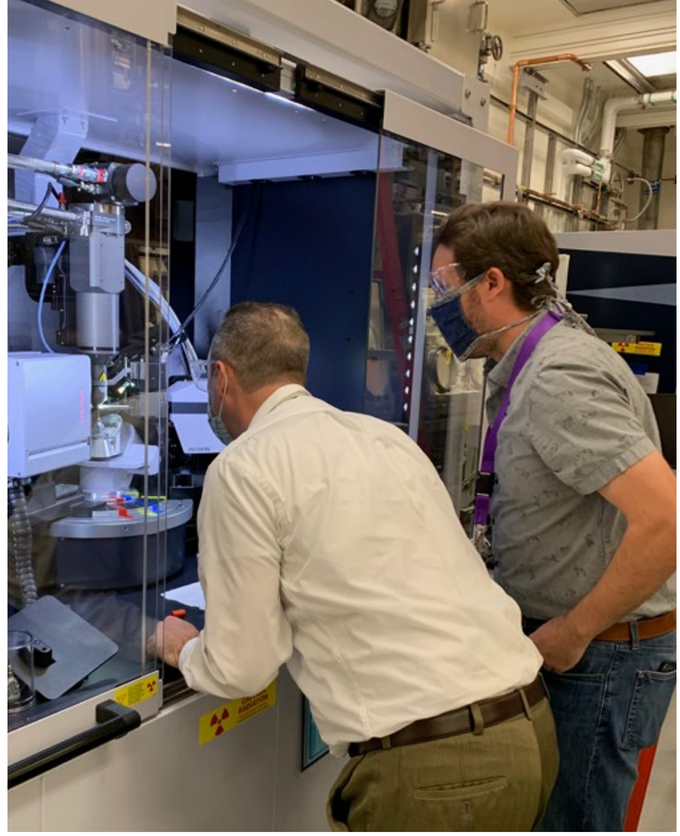
Top: Gio Romero fabricates one of many unique plutonium experimental sample holders. Below: A plutonium sample destined to be loaded and shipped to an off-site destination.

Expertly provisioning continued …

Although the team routinely works on complicated experiments, those for the Z machine are among the most challenging, Mitchell said, with specifications that require planning to begin up to a year before the actual experiment.

First, team members work with principal investigators to determine the experiment's goals. They then help create a custom design—choosing the right material for the specific experiment and making sure it is in the right state from the beginning. "The sample prep and loading is different for almost every experiment," he said, and requires collaboration across the Laboratory and between LANL and Sandia. To reduce oxidation—and contribute to the best experimental outcome—the team will cut and polish the sample "so that it is as fresh as possible before it is loaded into the sample holder," Mitchell said.

Such specialized skill and knowledge takes years to develop. Indeed, a subset of the team has nearly 70 years of combined experience in working with radiological materials. These veteran team members are essential to fostering the next generation of plutonium technicians, technologists, scientists, and engineers. "We have a lot of practical and technical knowledge that needs to be passed on," he said. "There is no substitute for the on-the-job training that we can provide." ■



From left: Paul Tobash and Adam Phelan load a sample into the new Radiological Laboratory Utility Office Building (or RLUOB) single-crystal diffractometer.

From left: Paul Tobash and Mark Wartenbe load a sample into a PPMS DynaCool system, used for measuring low-temperature physical properties.

Sigma Complex **direct cast innovations** support NNSA milestones

Los Alamos National Laboratory is a leader in the development of new manufacturing techniques and the application of mature techniques for new uses. To those ends, the Sigma Complex has recently been the epicenter of prototype development and technology readiness level (TRL) advancement for the direct cast process per NNSA's Advanced Manufacturing Development key milestones.

The development of direct cast technology as a robust process has been led locally by Robert Aikin (Fabrication Manufacturing Science, Sigma-1), who was recognized for this work with a 2019 Laboratory Distinguished Performance Award. The effort, however, also involves a large number of people from across the Laboratory and other NNSA sites.

The Sigma Foundry and Solidification Science Team maintains multiple large-scale melt technologies to fulfill needs from across the DOE Complex. Molds and processes are determined through a combination of experience, general design rules developed over years of investigation, and pen-to-paper number crunching. Designs are further tested through computational fluid dynamics simulations before being manufactured in-house and prepared for metal casting. A great deal of planning and effort goes into every specialized casting, which keeps the foundry team–just shy of 20 individuals–busy day in and day out.

While Sigma Division maintains as much manufacturing expertise as possible in one place, development efforts this large require resources across the Laboratory, notably including machining and inspection within Prototype Fabrication Division, chemical analysis by Chemistry Division, and radiography support provided by the Non-Destructive Testing and Evaluation Group. Managing such wide-ranging requirements while continuing to improve product quality is a daunting task. Delivering these components requires large amounts of specialized hands-on work, but also requires prompt and thorough reviews and approval from nearly every support organization on the Hill. A real sense of shared fate is required in order to achieve realization of new technologies.

Process development is always challenging because setbacks and failures are inevitable. Indeed they are critical to gain understanding, but the concepts are mature enough that expectations are success oriented.

Regarding how to overcome challenges inherent in new process development, Seth Imhoff (Sigma-1) expressed the importance of having perspective. "In the Sigma foundry there is an oft-repeated quote, attributed to the late-great Frank Zaner of Sandia National Laboratories, that is invoked when there is an unexpected failure: 'We must be getting close since Mother Nature herself is working to protect her secrets.' "

Fortunately, the yearly program demands for manufacture of one-of-a-kind components and systems keep the staff of Sigma and those of the organizations with which they partner across the Laboratory ready to quickly respond when challenges or new missions need solutions. ■

A small portion of the team responsible for direct cast process development at LANL pictured in front of one of Sigma Division's large induction furnaces. From left: Seth Imhoff, Bob Forsyth, Cody Miller, Kaegan Schultz, Bo Folks, Carl Osborn (behind Folks), Ryan Mier, Greg Sharp, Tom Jungst, Rob Aikin, Anthony Florez, Trevor Davis, and Ray Sandoval.

GET THE DETAILS

Direct Cast is a multi-program supported effort. At LANL, work is spread between multiple groups within the Physical Sciences (ALDPS) and Weapons Engineering (ALDW) directorates.

High-hazard operation delivers **mission-essential nuclear science and dynamic performance data**

— Team's extraordinary effort recognized with distinguished performance award

For a half century, the United States has looked to the Los Alamos Neutron Science Center (LANSCE) to deliver high-energy, high-power proton beams in support of national security science. The NNSA weapons program relies on LANSCE to help ensure the resilience of the nation's nuclear deterrent. As well, hundreds of users from around the world visit LANSCE to conduct their groundbreaking research. Patients across the country depend on LANSCE's isotopes for medical treatment.

The long-term success of this flagship DOE facility can be attributed to the combination of one of the highest power linear proton accelerators in the world and a wide variety of unique diagnostic and experimental capabilities.

Last year, this mission-critical facility encountered a failure in a portion of its accelerating structure that had never been seen before. A cracked weld on the inner surface of a drift tube linac tank caused the 4 x 62-foot structure to fail completely. This crack rendered the entire half-mile-long machine inoperable, putting essential work at the experimental facility in limbo.

Recognizing the consequences, a team of highly dedicated individuals from across the Laboratory mobilized to creatively diagnose and solve the problem, overcoming obstacles that challenged their expertise and called for extreme commitment.

The solution was one of a kind: a copper-to-copper direct weld of the crack done inside the long and narrow tank. Deemed "high hazard," the repair presented numerous risks, including working in a confined space, welding operations, and welding radioactive materials. To assess, evaluate, plan, monitor, and execute this difficult and challenging repair required the expertise of accelerator engineers and technicians, welding subject matter experts (SMEs), industrial hygienists, confined space experts, confined space rescue personnel, health physicists, and radiological control technicians.

From top: In an effort to assess the condition of the damaged tank, Nathan Kollarik threads a small camera deep into its interior and then with David Ballard views the transmitted images. A monitor displays –via remote camera–video of Jason Burkhart welding the crack inside the tank.

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High-hazard operation continued …

After months of planning, prepping, and practicing by the team, Jason Burkhart (Mechanical Design Engineering, AOT-MDE) maneuvered stomach-down more than 20 feet into the tank. With his colleagues outside the tank's access port assisting him and monitoring his progress via a camera transmitting video to a laptop, he painstakingly prepped the tank surface, expertly welded the crack, and then cleaned the tank.

When the work was complete, Gus Sinnis, the then LANSCE user facility director, said, "The welds look beautiful and speak to Jason's meticulous approach to the problem."

The team was recognized with a 2019 Laboratory Large Team Distinguished Performance Award for its efforts in executing this unique, high-consequence, and highly hazardous repair.

The result of this team's dedicated effort was the successful repair of the tank—and the return of the LANSCE accelerator to full power as well as the resumption of the LANSCE experimental programs.

When the beam was back up, Accelerator Operations and Technology Division Leader Stephen Milton reported, "The repair of the tank-3 drift tube linac was very successful and by all appearances looks to be performing better than it has in 10 years."

The team's work was a true example of simultaneous excellence, bringing together SMEs to approach a complex problem and deliberately execute the work to realize a unique and essential mission. ■

GET THE DETAILS

Participants: Members of Physical Sciences (ALDPS); Accelerator Operations and Technology (AOT-DO); Mechanical Design Engineering (AOT-MDE); Accelerator Operations (AOT-OPS); Instrumentation and Controls (AOT-IC); RF Engineering (AOT-RFE); Deployed ESH (DESH-DO); Deployed ESH LANSCE Facility Operations (DESH-LFO); Non-Destructive Testing and Evaluation (E-6); Engineering Project Delivery (ES-EPD); Institutional Quality (IQPA-IQ); LANSCE Facility Operations (LANSCE-FO); Logistics Maintenance Sub-Management (LOG-MSM); Industrial Safety and Hygiene (OSH-ISH); Radiation Protection Programs (RP-PROG). **Funding:** Maintenance and operations at LANSCE are funded by Weapons Infrastructure. **Technical contact:** Gary Hagermann

MEET GREG DALE

R&D engineer, Accelerators and Electrodynamics (AOT-AE)

In supporting the Lab's national security mission, Greg Dale not only develops solutions to complex technical challenges, he leads large multidisciplinary teams in implementing those solutions.

"I've been highly fortunate to get to work with so many great people at Los Alamos," Dale said. "The favorite part of my job is working with my colleagues to come up with clever solutions to problems of national importance."

Until recently, Dale led the Laboratory's molybdenum-99 (Mo-99) program, supporting the NNSA effort to establish the domestic commercial production of this radioisotope—used daily in tens of thousands of U.S. medical procedures—without the use of fissile highly enriched uranium. In successful collaborations with other DOE labs and commercial partners, he developed and implemented novel experiments at the Los Alamos Neutron Science Center and at other facilities that furthered the state of the radioisotope production. He represented LANL work at multiple international conferences and served as an NNSA technical representative at the National Academy of Sciences review of the program. For his part in bringing the first domestically produced Mo-99 to market in 30 years he was recognized by the Secretary of Energy.

Today, as the Scorpius Accelerator Subsystem Technical Lead, Dale oversees the development of a new generation linear induction accelerator essential for dynamic radiography plutonium experiments at the Nevada National Security Site. His role in leading the accelerator's technical development again taps his ability to build motivated teams across institutions focused on delivering national security science.

Dale, who has a PhD in electrical engineering from the University of Missouri-Columbia, joined the Laboratory in 2003. In Accelerator Operations and Technology, he continues to support cutting-edge projects in advancing pulsed power, accelerator, and high-power radio-frequency technology. ■

Novel study reveals new details on the **impact of thermal interfaces in dynamic compression experiments**

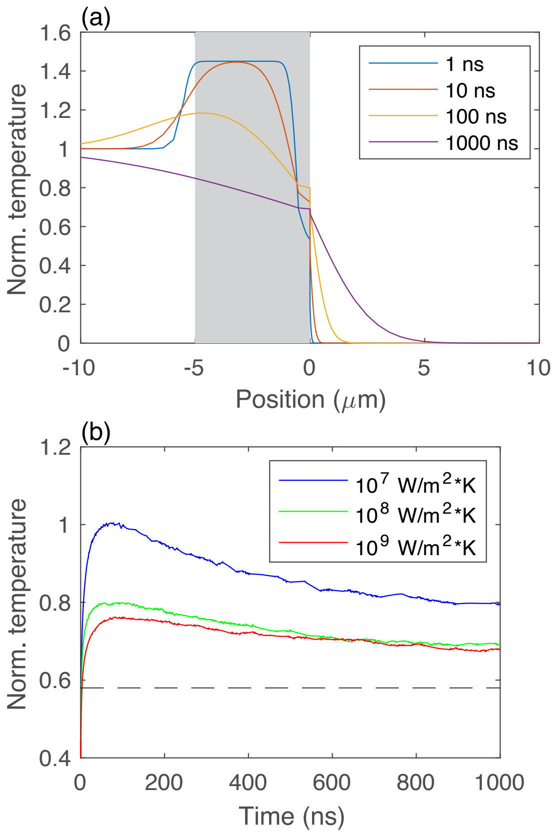
Temperature is an important, yet difficult, thermodynamic variable to measure in dynamic compression experiments. In particular for materials under dynamic compression, time-resolved temperature measurements are essential to understanding the physics influencing phenomena that range from equation of state to phase transition and chemical reaction.

In work chosen as an "Editor's pick" in the *Journal of Applied Physics*, Thomas Hartsfield (Neutron Science and Technology, P-23) and collaborators from the Nevada National Security Site and Sandia National Laboratories have shown that understanding the interface physics at play is even more important than precise temperature measurement when seeking to understand and predict the behavior of materials in such extreme environments.

"While optical pyrometry is a general-purpose technique for measuring temperature from a radiant surface, that surface is often the interface between distinct materials with temperatures that vary spatially along the loading direction," Hartsfield said. "As a result, interpreting dynamic temperature measurements remains a fundamental challenge."

Leveraging Los Alamos expertise in experiment design, diagnostic development, data analysis, and materials modeling, the researchers created and measured a series of varying thermal interfaces under shock compression. Comparing the results of these experiments to numerical analysis of the loading path and thermal diffusion at the measurement interface, the researchers discovered that shock wave interactions rapidly create and leave behind a complex local thermal profile. At the measurement point, material temperature subsequently evolves at longer characteristic timescales throughout the duration of the experiment. As a result, seemingly subtle changes in experiment geometry lead to very different temperature profiles that vary in time.

This insight into the thermal and mechanical physics driving interface properties in dynamic compression experiments allowed the researchers to explain how the temperature of that interface relates to the fundamental bulk thermodynamic state that is used to improve the material models used in the Laboratory's hydrodynamics codes. ■



The initial (top, normalized) temperature profile created by dynamic compression spatially varies across the measurement interface at 0 μm. Time-evolution of the temperature at that interface (bottom) shows how thermal diffusion produces interface temperatures that vary in comparison to the bulk thermodynamic material state (set to unity) of interest.

GET THE DETAILS

Mission connection: The work supports the Laboratory's Stockpile Stewardship mission area and its Materials for the Future science pillar. **Funding:** The Los Alamos portion of the research was funded by the Dynamic Materials Properties Campaign (LANL Program Manager Dana Dattelbaum, Project Leader Garry Maskaly). **Researchers:** Thomas Hartsfield (Neutron Science and Technology, P-23); Brandon LaLone, Gerald Stevens, Lynn Veeser (Nevada National Security Site); Dan Dolan (Sandia National Laboratories). Reference: "Thermal interfaces in dynamic compression experiments," *Journal of Applied Physics,* 128 (2020). **Technical contact:** Thomas Hartsfield

First-ever actinide-zirconium framework synthesized — *Work relevant to storage and environmental fate of nuclear waste*

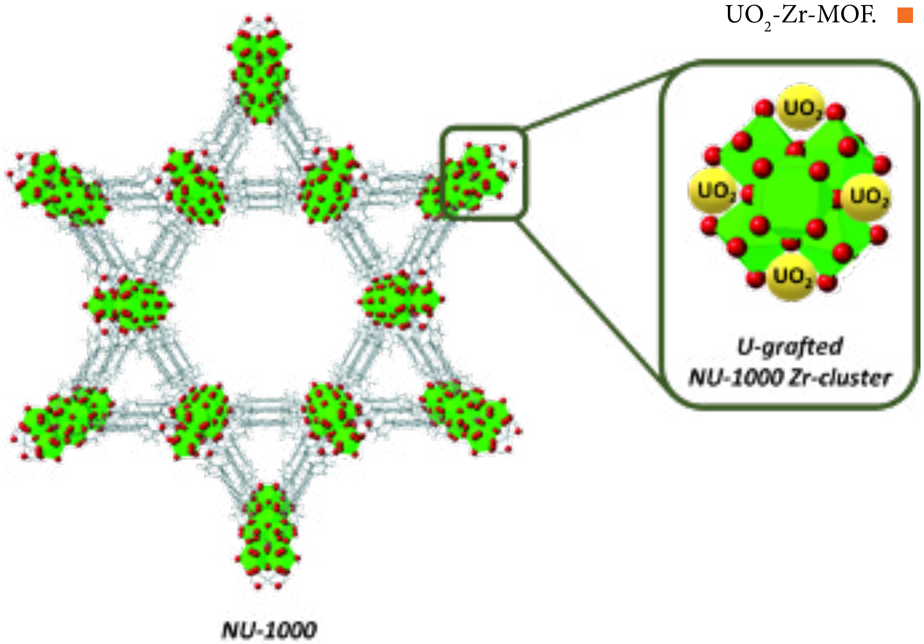
Accurately characterizing actinide species bound to metal–organic frameworks (MOFs) is important for understanding these structures as potential radioactive waste forms and providing new models of actinide species transport in the environment. MOFs are highly tunable, porous, crystalline solids with extended structures that self-assemble from inorganic nodes and organic linkers.

Zirconium-based MOFs (Zr-MOFs) exhibit a diversity of topologies along with high chemical and thermal stability and are often accessible by scalable and green syntheses. Due to the stability of MOFs and their ability to uptake high concentrations of contaminants, they are potential nuclear waste forms. Additionally, the interaction of the uranyl species with the Zr oxide cluster provides a model for mineral absorption and transport that is easier to characterize than similar species absorbed to surfaces.

In work appearing in *Crystal Engineering Communications*, Los Alamos researchers and their external colleagues used solvothermal deposition to synthesize a uranyl-grafted framework, thus creating a single-crystal structure that is the first reported actinide ion bound in the channel of a Zr-MOF.

Hierarchical Zr-MOF was prepared in collaboration between scientists in Materials Synthesis and Integrated Devices (MPA-11) and Northwestern University. This MOF was post-synthetically modified to introduce uranyl ion into the Zr-oxide cluster unit of the MOF.

Analysis of the chemical composition of the crystals by scanning electron microscopy and Raman spectroscopy at LANL revealed that uranyl cations are dispersed uniformly throughout the crystal and incorporate into the framework through binding of the Zr-oxide cluster rather than metal exchange. These findings were further corroborated through determination of the single-crystal x-ray diffraction pattern for the UO_2-Zr-MOF. ■



The MOF NU-1000 is comprised of Zr-oxide clusters (green polyhedrons with red oxygen atoms) linked together with organic linkers (gray). The uranyl species, UO_2^{2+} (yellow), binds to the Zr-oxide polyhedra through the oxygen atoms of the polyhedra.

GET THE DETAILS

Mission connection: The work supports the Laboratory's Energy Security mission and its Materials for the Future science pillar. **Funding:** The Los Alamos portion of the work was funded by the Laboratory Directed Research and Development Program. **Researchers:** Tatyana Elkin, Brian L. Scott (Materials Synthesis and Integrated Devices, MPA-11); Laura E. Wolfsberg (Inorganic, Isotope, and Actinide Chemistry, C-IIAC); and Julia G. Knapp, Xuan Zhang, Sylvia L. Hanna, Florencia A. Son, and Omar K. Farha (Northwestern University). **Reference:** "Single crystal structure and photocatalytic behavior of grafted uranyl on the Zr-node of a pyrene-based metal–organic framework," *CrystEngComm*, 22 (2020). **Technical contact:** Brian Scott

Summer Physics Camp takes a virtual turn

Even as COVID-19 was keeping New Mexico residents at home and socially distanced, Anna Llobet knew the Los Alamos Summer Physics Camp for Young Women must go on.

It would just be a bit different than in the past.

Yes, the camp still offered more than 20 young women from Northern New Mexico a unique chance to meet a broad range of female and male role models across STEM fields—including astrophysics, engineering, computer science, and chemistry—and to learn about opportunities at LANL. However, this year the event was adapted to a completely virtual experience, with students attending from their homes and volunteers joining from as far as Europe.

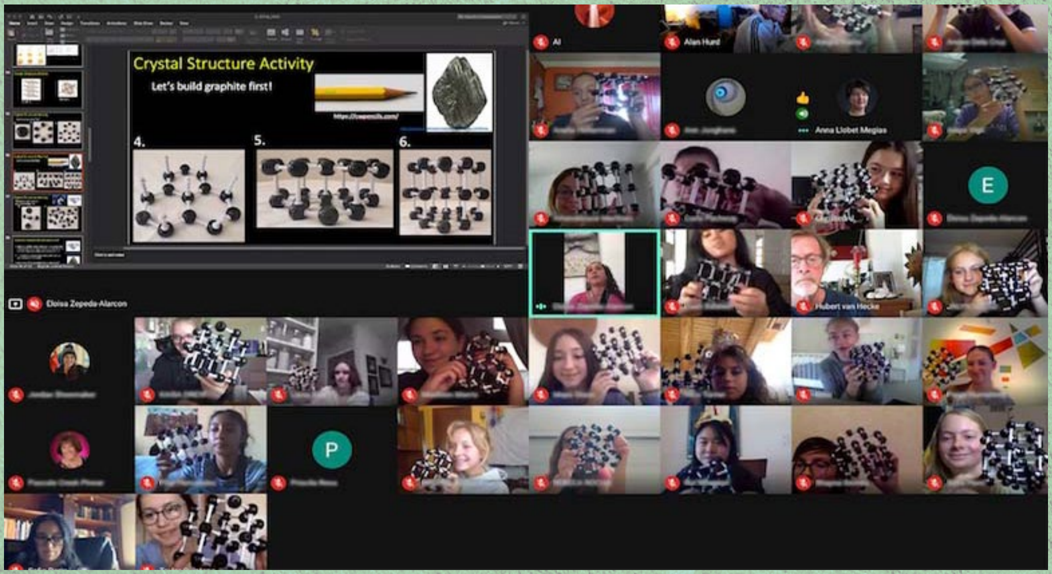
Developing a virtual camp at short notice was not easy, said Llobet (Neutron Science and Technology, P-23). However, she and the nearly 90 camp volunteers were still "excited to inspire our local youth and make them realize that they too can change the world and one day be part of LANL's workforce or inspire the love for STEM in their communities through education."

The transition was made possible with support from the Laboratory, the New Mexico Consortium, LANL Foundation, Los Alamos and Pojoaque Valley schools, the Athena Engineering Scholars Program, Oak Ridge Computer Science Girls, and the Institute of Electrical and Electronics Engineers.

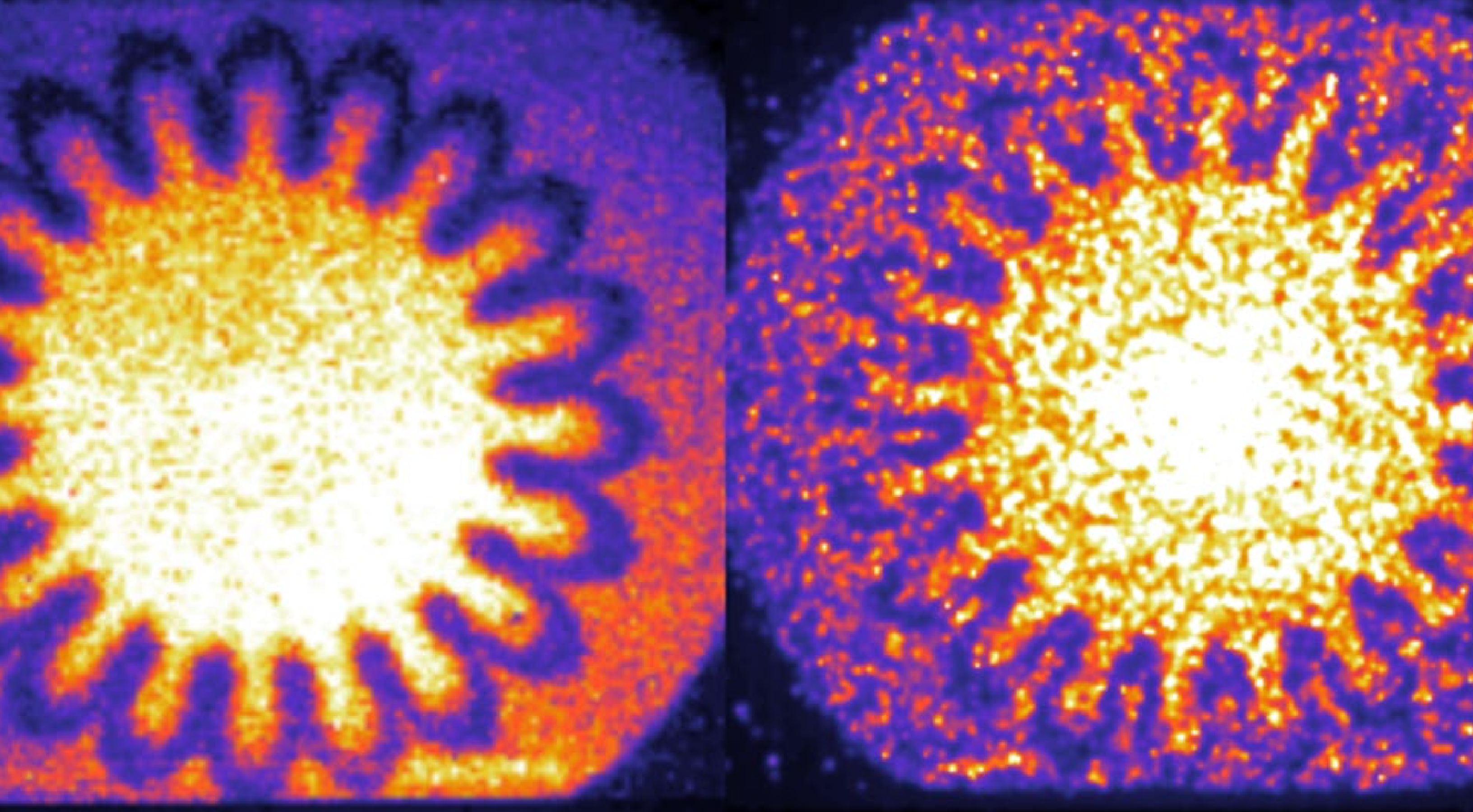
Guest presenters included Emily Calandrelli, TV host of *Xploration Outerspace*; Heather Bottom, NASA Jet Propulsion Laboratory systems engineer; Thomas Proffen and Catherine Schuman, data analytics experts from Oak Ridge National Laboratory; Dr. Pascale Creek Pinner, Albert Einstein Distinguished Educator Fellow and 2008 Hawaii Teacher of the Year; and Hawi Stecher, STARBASE Hawaii instructor.

The 2020 group represented the New Mexico communities of Acalde, Chimayó, Española, Los Alamos, Santa Cruz, Santa Fe, and White Rock. For the first time this year, four students attended from Hilo, Hawaii, through a partnership with and support from the Thirty Meter Telescope International Observatory and the Hawaii Science and Technology Museum.

More than half of the two-week camp was dedicated to hands-on experiments, demonstrations, engineering challenges, and coding adventures. Several New Mexico colleges and LANL student programs joined the camp and shared local opportunities for future careers in STEM. Each student received a package of materials for demos and experiments to help them learn about topics that included atomic structures, turbulence, the fundamental properties of light, electric circuits, electromagnetism, and computing and robotics—including the chance to explore coding on a Raspberry Pi and manipulate an Arduino board. ■



Students and instructors at the Summer Physics Camp for Young Women show the results of one of their hands-on experiments.



The LANL Inertial Confinement Fusion Program aims to develop burning plasma for weapons science. Understanding instability growth and ways to mitigate it is vital to achieving ignition in inertial confinement fusion capsules. In support of this effort, Plasma Physics (P-24) researchers demonstrated near identical hydrodynamic growth in cylindrical implosions at two different facilities. The images above are x-ray radiographs of cylindrical implosion taken at the Omega Laser Facility (left) and the National Ignition Facility (right). Despite different temporal and spatial scales, nearly identical instability growth was observed at both facilities.

Associate Laboratory Director for Physical Sciences:
Antoinette J. Taylor

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